Sustainable agricultural development in rural Sudan

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Abstract: This study assesses the extent of poverty in rural Sudan. It is focusing on the indicators and identifying the causes of poverty, trends and tenable solutions by farming systems. Additionally it is drawing an optimal cropping pattern for rural poor households that have optimised resources and reduced poverty. An insightful analysis was performed to impute the poverty alleviation measures by individual crops and the levels of technology applied. The findings of this study indicate that the incidence of poverty was higher in traditional and mechanised farms when contrasted with those using irrigated farming technologies. The female-headed households are poorer compared to the male-headed households. The linear programming associated with the Policy Analysis Matrix (PAM) has explained that the misuse of resources and the lack of appropriate technologies were among the important factors that led to the low returns from farming and persistent poverty in the countryside. The PAM results also showed that the poor producers grow food crops only to maintain self-sufficiency and do not buy expensive food from the markets. Food crops have more comparative advantage in the investigated three farming systems. Accordingly, reversed credit policies that favour more subsistent farm households should be imperative for boosting production and reducing poverty in rural Sudan.

1 Introduction

The agriculture sector in Sudan is the main livelihood sector in the Sudanese economy in terms of its contribution to the gross domestic product (about 39%) in 2005 (Sudan Bank, 2005). The annual per capita income in Sudan is currently estimated to be $300, which puts it among the least developed countries of the world (Sudan Bank, 2006).

The poor economic performance during the last two decades had been triggered mainly by the spreading long civil war, ethnic conflicts and recurrent famine. Famine was often initiated by frequent episodes of drought that struck Sudan and complicated by poor policies. Poverty in Sudan is a multidimensional problem involving economic, political, social as well as ecological factors (Fergany, 1997; Deng, 2004). Poverty in Sudan is widespread, particularly in rural areas, with the degree of poverty in Sudan at about 83% for both rural and urban populations (Nour, 1996). Worse, an IFAD (2006) study suggested that 90% of the population of Sudan can be classified as poor.

2 Motivations and purposes of the study

Most rural people in developing countries are highly dependent on resource-based subsistence economies using products obtained from plants and animals. However, a large portion of Sudan's rural people today live in highly degraded lands and vulnerable environments, which put them in a contentious struggle to maintain their needs. Rural Sudan is facing food deficits in many of its regions. During the recent past, a number of key changes have occurred that combined to profoundly affect the lives of the poor inhabitants in Sudan. Farming households are faced with two main aspects: the natural aspect and the economic aspect. The unexpected changes and fluctuations in the environment lead to the low production of food and cash crops and deterioration of pastures. On the economic side, the formulation of the price policy has not favoured the main food and export commodities, which would ultimately result in poverty incidence. In addition, the unfair resources allocation leads to conflicts and civil wars all over the country and obliges the rural population to migrate from their homes and seek shelter, food and water in worthy and secured regions; their ultimate end would be to fall into food security and live in the poverty sphere.

The overall purpose of this study is to address poverty and environmental problems within a context of policy analysis. The specific purposes of the study are threefold:

1. to examine the indicators and causes of poverty in rural Sudan
2. to analyse the economic efficiency of crops production of the rural poor in dominant farming systems
3. to assess the effects of intervention of different variables, such as the introduction of new technologies.

3 Methodologies and analytical techniques

This study is based on both primary and supportive secondary data sources. The primary data are collected from a household survey using instrumental questionnaires. The study covered three production domains: traditional rainfed (rural Kordofan state), mechanised rainfed (rural Blue Nile state) and irrigated farms (rural Gezira state). The collected rural poverty information included: socioeconomic information, land use, ownership patterns, food issues, economic activities, and drinking water and health aspects.

3.1 Poverty lines, indicators and causes

Energy-built calorie-based poverty lines are widely used around the world (Deaton, 2004). Two approaches are applied to establish the poverty line in rural areas the Food Energy Intakes (FEI) approach and Costs of Basic Needs (CBN) approach, which concentrates on the degree of fulfilment of basic human needs in terms of health, food, education, water, shelter and transport (Streeten *et al.*, 1981). The food poverty line is calculated from the main common food basket used in rural areas and the daily consumption is calculated based on the adult equivalent. According to Foster *et al.* (1984), the poverty measure is defined as follows:[1]

$$p^{\alpha} = \frac{1}{n}\sum_{1}^{q}\left[\frac{z-y}{z}\right]^{\alpha} \tag{1}$$

where:

n = the total number of individuals under consideration
q = the total number of poor people
y = the income of the i-th poor individual
z = the poverty line
α = a parameter characterising the degree of poverty aversion.

For z, most of the literature uses the national absolute poverty line (Hulme *et al.*, 2001; Ibrahim, 2003). The indictors of poverty measured are:

- *Headcount ratio (H)*, which gives the proportion of the population for which consumption or income y is less than the poverty line z (generated when the parameter α is equal to 0).
- *Poverty gap ratio (PG)*, which represents the depth of poverty (generated when the parameter α is equal to 1).
- *Poverty severity (PS)*, which reflects the inequality among the poor (generated when the parameter α is equal to 2).

A Binary Logistic Regression (BLR) analysis was undertaken to determine which factors were significantly associated with poverty movements (Kristjanson *et al.*, 2006). The BLR used to built a model directly estimates the probability of an event's occurrence. The dependent variable (the status of the household's livelihood) is dichotomous (1 for extremely poor and 0 for nonpoor). The model is used to derive the estimates of the odds ratio for each factor contributing to the poverty incidence. The independent variables considered in the analysis were: age, occupation, household's size, education level of the household head, diseases affecting the household's members, water sources, gender, *etc*.

The binary logistic regression is specified as:

$$Z_i = \breve{a}_j + \beta_i W_{hij} + \varepsilon_{hi} \tag{2}$$

where z_i is the value of the unobserved explanatory variable for the i-th case; it is a binary variable indicating whether a household is below the extreme poverty line or not (1 if extremely poor, 0 if not). Also, Z_i can be expressed as follows: W_{hij} is the j-th predictor for the i-th case of the selected demographic and socio-economic characteristics of being poor. β_i is the i-th coefficient of W_{hi}, $\breve{a}_j$ = a cluster fixed or constant effect, ε_{hi} = a random error term assumed uncorrelated with the regressors.

The probability of being extremely poor depends on a set of variables W so that:

$$\text{Prob}\ (z_i\ 1)\ F\ (\beta_i W_{hi}) \quad (3)$$

$$\text{Prob}\ (z_i\ 0)\ 1 - F\ (\beta_i W_{hi}) \quad (4)$$

where Z_i is the household total expenditure. The probability of being extremely poor depends on a set of variables W so that:

$$\text{Prob}\ (z_i = 1) = p\ (z_i > 0) = f\ (\check{a}_j + \beta_i W_{hij}). \quad (5)$$

3.2 PAM analysis

The linear programming associated with PAM was analysed using General Algebraic Modeling Systems (GAMS) software. Recently, several studies have used PAM that relates the above parameters of comparative advantage and policy effects (Masters and Winter-Nelson, 1995; Khan, 1997; 2001; 2002; 2004; Mohanty *et al.*, 2002; Khan and Akhtar, 2005; Hussain *et al.*, 2006; Atiya, 2007).

PAM was developed by Monke and Pearson (1989) and augmented by Masters and Winter-Nelson (1995) for measuring input use efficiency in production, comparative advantage and the degree of government interventions. The basis of PAM is a set of profit and loss identities, *i.e.*, a matrix of two-way accounting identities (Nelson and Panggabean, 1991). Furthermore, Monke and Pearson (1989) established the basic format of PAM, as shown in Table 1.

Table 1 Policy matrix analysis

		Value of input		
Prices (accounts)	*Value of output (revenue)*	*Tradable input cost*	*Non-tradable input cost (domestic factor)*	*Profit*
Private prices	A	B	C	N
Social prices	D	E	F	O
Policy transfer (divergence)	G	H	I	P

Notes: Private profit: N = A – (B + C); Social profit: O = D – (E + F); Output transfer: G = A – D; Input transfer: H = B – E; Factor transfer: I = C –F; Net policy transfer: P = N – O.

Source: Monke and Pearson (1989)

Revenues, costs (tradable and nontradable inputs) and profits are calculated using two sets of prices: Set A denotes the prices that private agents actually face in the market and Set B denotes the social prices that measure the opportunity costs to the economy of using resource or domestic factors. Yao (1997) stated that the most difficult task for constructing a PAM is the estimation of social prices for outputs and inputs. To compute the social prices for various commodities, including both inputs and outputs, world prices are used as the reference prices in the study. The difference between private and social prices reflects the size of transfers which are either fed in or taken out of the system by all kinds of government intervention and market distortions. All values are expressed per unit of output.

Tradable inputs include those inputs which can be traded in the world market, *e.g.*, imported fertilisers and pesticides. Nontradable inputs are mainly domestic factors that are not traded internationally, *e.g.*, land, labour and local capital. In empirical PAM analysis, the revenue and cost categories in private prices (entries A, B and C) are based on data from farm and processing budgets. The data in the first row provide a measure of private profitability (N), defined as the difference between the observed revenue (A) and costs (B + C). The second row of the matrix calculates the social profit that reflects the social opportunity costs. Social profits measure efficiency and comparative advantage. In addition, the comparison of private and social (efficiency) profits provides a measure of efficiency. The third row of the matrix estimates the difference between the private and social values of revenues, costs and profits, which can be explained by policy interventions.

The social (efficiency) prices for the domestic factors of production (land, labour and capital) are also estimated by the application of the social opportunity cost principle. Because domestic factors are not tradable internationally and do not have world prices, their social opportunity costs are estimated through the observations of rural factor markets (Pearson *et al.*, 2003). The PAM framework is also used to calculate the important indicators for policy analysis, *e.g.*, the Nominal Protection Coefficients (NPCs). The NPC is a simple indicator of the incentives or disincentives in place and defined as the ratio of the domestic price to a comparable world (social) price. NPC can be calculated for both output Nominal Protection Coefficient of Output (NPCO) and Input (NPCI). NPCO is the ratio between the private and social revenue of the output (*i.e.*, the ratio of the domestic market price of the product to its parity price at the farm). If NPCO > 1, it indicates that the private price of output is greater than its parity price; hence, producers are positively protected for the product. If NPCO < 1, it indicates that producers are implicitly taxed on the product. If NPCO = 1, it indicates a neutral situation. NPCI is the ratio of the private to social cost of tradable inputs (*i.e.*, the ratio of the private to social values of all the tradable inputs). If NPCI > 1, it indicates that producers are taxed when they buy tradable inputs. If NPCI < 1, it indicates that they are subsidised. NPCI = 1 represents a neutral situation. The other indicator used is the Effective Protection Coefficient (EPC). EPC measures the total effects of intervention in both input and output markets. EPC is the ratio of the added value measured at private prices (A–B) to that of social prices (E–F). An EPC value greater than 1 suggests that government policies provide positive incentives to producers, *i.e.*, the overall impact of the existing policy results in a net positive incentive to produce the commodity, while an EPC value less than 1 indicates that producers are not protected through policy interventions (it represents a net disincentive). EPC = 1 implies either no intervention or that the net impact of various distortions on both the input and product markets results in a neutral effect on the value added.

The various indicators are used to compare the relative efficiency or comparative advantage between agricultural commodities. In this study, the Domestic Resource Cost (DRC) and Private Profit Coefficient (PPC) indicators are used. DRC has been widely used in developing countries to measure efficiency or comparative advantage and guide policy reforms (World Bank, 1991b; Appleyard, 1987; Morris, 1990; Gonzales *et al.*, 1993; Alpine and Pickett, 1993; Mohanty *et al.*, 2002). DRC is defined as the shadow value of the nontradable factor inputs used in an activity per unit of tradable value added (F/(D – E)). DRC indicates whether the use of domestic factors is socially profitable (DRC < 1) or not (DRC > 1). The DRC values are calculated for each crop in each farm.

The crops can be ranked according to the DRC values and this ranking is taken as an indication of the comparative advantage or disadvantage within that state. A farm will have a comparative advantage in a given crop if the value of the DRC for that crop is lower than the DRC for the other crops grown in that farm. The data requirements for constructing PAM in this study include yields, input requirements and the market prices for inputs and outputs. Import/Export tariffs and exchange rates are also required to calculate the social prices.

4 Results and discussions

4.1 Food poverty lines in rural Sudan

The estimated food poverty line in mechanised farms is equal to \$0.17 per day per person, while those of irrigated and traditional farms are \$0.14 and \$0.34 per person per day, respectively. Similarly, the extreme poverty line of the traditional farms is \$0.41 per person per day, whilst that of the mechanised and irrigated farms are \$0.21 and \$0.16 per person per day.

Armed conflicts, including civil wars, have exacerbated the existing poverty and extended its prevalence geographically and socially into hitherto unaffected regions and social classes compared to those that occurred in Lebanon and Yemen (affected by civil strife) and contrasted to those in Egypt, Jordan and Palestine, which were affected indirectly by the Gulf War (El-Solh, 2003).

The highest number of rural poor people is found in the traditional farms (91%), followed by the mechanised farms (85.4%) and the irrigated farms (66.7%). From Table 2, it is obvious that the headcount ratio, poverty gap ratio and poverty severity in the traditional farms (rural Kordofan state) are high in comparison with those of other farms. These results imply that poverty in rural Sudan over 2005–2006 had been more widely spread and deep in traditional and mechanised farms than in the irrigated farms. The variations in the standards of living and the incidence of poverty are particularly related to the differences in agroclimatic/geographical conditions (Gunasena, 2003).

Table 2 Poverty index, depth and severity in rural Sudan by farm (%)

	Farming systems		
Poverty measures	*Mechanised*	*Irrigated*	*Traditional*
Poverty index (H)	85.4	74.1	97.8
Poverty depth (PG)	65.1	54.9	93.7
Poverty square (PS)	49.6	40.6	89.7

Source: Field survey, season 2005/2006 collected by the authors

4.2 Poverty status in rural Sudan

The socioeconomic characteristics of rural poor households are expected to have great effects on the poverty incidences in the study areas. The educational attainment of the head of the household is found to be among the important factors associated with poverty (Elsheikh and Siwar, 2004; Chadha, 2002; Dasgupta, 1989). The results indicate that the majority of the poor rural household heads are illiterate. The estimated illiteracy in the irrigated farms (68.1%) and traditional farms (62.5%) are more than those in the mechanised farms (49.3%). Consequently, the opportunities to continue education beyond the primary level are limited, as many rural poor cannot attend secondary schooling. Travelling long distances for school and the lack of financial resources to pay fees or purchase uniforms and notebooks are the main factors that rural poor face when sending their children to school. More than half of the poor children are enrolled in schools and unable to resume their education because of tuition fees.

Many studies have shown that occupational categories affect the depth of poverty (Dreze *et al.*, 1992; Angelsen and Kaimowitz, 1999).

Agriculture remains the main source of livelihood of the rural people in the surveyed farms, as more than half of the population derive their livelihood from land. Majority of the poor rural households in all farms were fully occupied with their tenancies (had no off-farm occupation). The results indicate that the poor households own agricultural land, but lack the appropriate technology and the removal of subsidies from production inputs (*e.g.*, from fertilisers), which make these the main factors for being poor in these farms. Most of the land is not occupied efficiently to satisfy the rural households' needs.

Peden *et al.* (2005) and Thornton *et al.* (2002) reported that livestock are one of the major assets that households accumulate as a result of their efforts to climb out of poverty. This indicates that there is a high incidence of poverty links with poor households that do not own livestock. Furthermore, the survey results found that about 90% of the poor households suffered from water-borne diseases, especially malaria and bilharzias.

Water resource scarcity is a major constraint in all the surveyed agricultural farms. Poor sanitation and the lack of access to clean water explain why diarrhea-related diseases are major sources of illness in the surveyed farms. Also, a small percentage of the rural poor rely on safe water taps for their water supply. For the last three decades, many women's advocates have argued that women are poorer than men (Cagatay, 1998; Székely, 1998; Regehr, 2006; Chant, 2003; Beneria and Bisnath, 1996).

The results show that female-headed households are poorer that male-headed households. This result presents that the majority of the poor female-headed households are found in mechanised farms. Many observers have noted that poverty and violence go hand in hand (Miguel, 2003). Also, the results show that the poor households do not own houses or obviously lost their houses during the war. Houses in rural Sudan are constructed from collected wild dry straw (shrub and scrub) and residues of crop products or mud.

4.3 Poverty causes in rural Sudan

In past decades, many researchers estimated the causes of poverty using different regressions models (Kyereme and Thorbecke, 1991; Rodriguez and Smith, 1994; Coulombe and McKay, 1996; Dudek, 2006; Krishna *et al.*, 2006; Francis, 2006). The study results argued that the poverty causes were heterogeneous according to the habits, norms and ethnicity of the poor in the various agricultural farming systems. It is clear that the main poverty determinants in the mechanised farms are related to the gender of the households' members and the age of the household head, which increase the likelihood of being in a higher poverty status (Table 3). The World Bank (1991a) and Lanjouw and Ravallion (1994) argued that large households tend to be associated with poverty. Moreover, households with a large number of males and females have an increased likelihood of being in a higher poverty status.

Table 3 Poverty causes in mechanised farms (rural Blue Nile state)

Variable	*Estimated coefficient* (β)[a]	*Standard error*	*Wad*	*Odds ratio exp* (β)	*95% of CI for odds ratio*	
					Lower	*Upper*
GENDER	0.105	0.918	0.13	1.111	0.184	6.717
AGE	0.045	0.034	1.709	1.046	0.978	1.118
EDUCALEVEL	–0.247	0.188	1.737	0.781	0.541	1.128
MERITALS	0.214	0.1554	0.149	1.239	0.418	3.669
SECDOCCU	–0.083	0.199	0.174	0.921	0.624	1.359
FAMSIZE	–0.068	0.183	0.138	0.934	0.652	1.338
NOMALE	0.020	0.090	0.049	1.020	0.855	1.217
NOFEMAL	0.172	0.279	0.381	1.188	0.687	2.054
DIDYOUW	–0.543	0.681	0.635	0.581	0.153	2.209
HAVDISEA	1.627	1.151	2.000	5.090	0.534	48.562
CONSTANT	–0.317	2.528	0.016	0.728		

Regression statistics:

Number of observations = 240

Likelihood ratio test: $X^2_{0.05}$ (10) = 12.695

Adjusted R-squared: 0.164

2-Log likelihood = 93.612

Notes: [a] Indicates statistical significance at $\alpha = 0.05$.

The variables in Table 3 are defined as follows:

A. Dependent variable

A binary variable indicates whether a household is below the extreme poverty line or not (1 if extremely poor, 0 if not). Poverty is estimated based on consumption per adult equivalent.

B. Explanatory variables

GENDER: A binary variable indicating whether the household head is female or male (1 if female, 0 if male).

AGE: The age of the household head.

EDUCALEVEL: A binary variable indicating whether the household head received education (primary, secondary, higher or professional education) or not (1 if educated, 0 otherwise).

MERITALS: A binary variable indicating whether the household head is married or not (1 if married, 0 otherwise).

SECDOCCU: A binary variable indicating whether the household head works in a secondary occupation or not (1 if he/she has a secondary occupation, 0 otherwise).

FAMSIZE: The size of the household.

NOMALE: Number of male children in the household.

NOFEMAL: Number of female children in the households.

DIDYOUW: Performance of agricultural activities by the household members (1 if they work in the field by themselves, 0 otherwise).

HAVDISEA: Suffering from diseases last year (1 if they suffer from diseases, 0 otherwise).

The results indicate that having an educated household head reduces the likelihood of being in a higher poverty status. Also, the agricultural activities performed by household members significantly reduce the likelihood of being in a higher poverty status.

In contrast, our results with irrigated farms show that the variables that are positively correlated with the probability of being poor are the size of the household, the number of children in the household and working in a secondary occupation and being affected by diseases, while the variables that are negatively correlated with the probability of being poor are gender, the age of the household head, the education level of the household head and household members performing agricultural activities (Table 4).

Table 4 Poverty causes in irrigated farms (rural Gezira state)

Variable	*Estimated coefficient (β)*[a]	*Standard error*	*Wad*	*Odds ratio exp (β)*	*95% of CI for odds ratio*	
					Lower	*Upper*
GENDER	–0.469	0.479	0.957	0.626	0.245	1.600
AGE	–0.005	0.014	0.140	0.995	0.969	1.022
EDUCALEVEL	–0.274	0.143	3.662	0.760	0.574	1.007
MERITALS	–0.315	0.184	2.929	0.730	0.509	1.047
SECDOCCU	0.002	0.099	0.000	1.002	0.825	1.216
FAMSIZE	0.669	0.693	0.931	1.512	0.132	1.993
NOMALE	0.719	0.694	1.074	2.052	0.527	7.992
NOFEMAL	0.722	0.680	1.128	2.058	0.543	7.800
DIDYOUW	–1.152	0.324	12.623	0.316	0.167	0.597
HAVDISEA	0.296	0.569	0.270	1.344	0.440	4.101
CONSTANT	3.762	1.559	5.819	43.022		

Regression statistics:

Number of observations = 240

Likelihood ratio test: $X^2_{0.05}$ (10) = 34.691

Adjusted R-squared: 0.200

2-Log likelihood = 250.613

Note: [a] Indicates statistical significance at $\alpha = 0.05$.

In traditional farms, the risk of poverty was on average lower in households with a male head and headed by young persons. Also, the risk of poverty was on average lower in households with a head possessing vocational education compared with households where the head has only informal or primary education. The households with extra occupations and have more family members working in the farms have a reduced likelihood of being in a higher poverty status (Table 5).

Table 5 Poverty causes in traditional farms (rural Kordofan state)

Variable	*Estimated coefficient (β)*[a]	*Standard error*	*Wad*	*Odds ratio exp (β)*	*95% of CI for odds ratio*	
					Lower	*Upper*
GENDER	−1.046	1.371	0.582	0.351	0.024	5.158
AGE	–0.005	0.039	0.015	0.995	0.922	1.074
EDUCALEVEL	–0.246	0.426	0.332	0.782	0.339	1.803
MERITALS	1.478	1.004	2.167	4.384	0.613	31.372
SECDOCCU	−1.660	1.049	2.502	5.258	0.672	41.120
FAMSIZE	1.897	1.405	1.822	1.150	0.010	2.356
NOMALE	2.081	1.445	2.074	8.016	0.472	136.180
NOFEMAL	1.789	1.402	1.629	5.983	0.384	93.331
DIDYOUW	–0.584	0.999	0.342	0.558	0.079	3.950
HAVDISEA	0.79	1.290	0.004	1.924	0.074	11.574
CONSTANT	1.276	4.396	0.084	3.581		

Regression statistics:

Number of observations = 240

Likelihood ratio test: $X^2_{0.05}$ (10) = 11.407

Adjusted R-squared: 0.270

2-Log likelihood = 39.465

Note: [a] Indicates statistical significance at $\alpha = 0.05$.

4.4 Interpretation of PMA results

Rural and urban poverty reduction can be accelerated by the growth of the rural sector, especially agriculture[2] (Ravallion and Datt, 1996). Higher productivity growth benefits both the urban and rural poor (Hayami and Herdt, 1977; Alauddin and Tisdell, 1991). Growth in agriculture and its productivity are considered essential in achieving sustainable growth and a significant reduction in poverty in developing countries (Prasada Rao *et al*., 2004; Mellor, 2001) Schubert (1994) noted a relationship between poverty and productivity.

The linear programming results explained that the misuse of resources and the lack of appropriate technologies were among the important factors that led to low returns from farming and persistent poverty among the rural poor.

One result of the study was the omission of staple food crops from the optimal model for the rural poor. Though, sorghum and millet are the most important staple food crops that constitute the main diet for the majority of rural Sudan including the commercial mechanized, traditional and irrigated farm households.

The results on the NPC for crops of the rural poor in various farms are reported in Table 6. The NPC in traditional farms is very close to 1, suggesting that the domestic price is slightly below the international price, whereas in the mechanised and irrigated farms, the NPCs are much more than 1. Similarly, the NPCI values of more than 1 in irrigated farms suggest that government policies increase the input costs for the major crops in all farms. The NPC values of less than 1 for all input and most output markets clearly show government efforts to support these irrigated farms.

Table 6 Summarised results of the protection coefficients for agricultural farming systems in Sudan (2005–2006)

Farm	*Protection coefficients*		
	NPCO	*NPCI*	*EPC*
1 *Mechanised*			
Sorghum	2.87	0.05	0.05
Millet	1.38	1.21	0.86
Groundnut	7.00	1.41	–1.39
Sesame	10.67	1.28	1.01
2 *Irrigated*			
Sorghum	1.26	0.19	0.18
Cotton	1.50	0.58	0.41
Groundnut	1.50	0.87	0.70
Vegetables	1.33	0.48	0.20
3 *Traditional*			
Sorghum	0.99	0.87	0.42
Millet	0.99	0.87	–2.24
Groundnut	0.91	0.89	0.89
Sesame	0.94	0.88	1.07
Watermelon	0.94	0.89	1.06

Notes: NPCO: Nominal Protection Coefficient of Output, NPCI: Nominal Protection Coefficient of Input, EPC: Effective Protection Coefficient.

Source: Calculated from authors' model, 2005–2006

The NPCO for crops in mechanised and irrigated farms are greater than 1, indicating that the private price of output is greater than its parity price; hence, producers in these farms are positively protected. In traditional farms, the NPCO is greater than 1, indicating that subsistence producers are implicitly taxed on the product or supply side, a policy-depressing factor for increased production in this largest agricultural sector.

The producers in mechanised farms are taxed when they buy tradable inputs (NPCI > 1), while the rural producers in irrigated and traditional farms are subsidised (NPCI < 1).

From the literature, the EPC is a more reliable indicator of effective policy incentives than the NPC, as the former recognises that the full impact of a set of policies includes both output price-enhancing effects (import tariffs) and cost-reducing effects (input subsidies). The EPC nets out the impact of protection on inputs and outputs and reveals the degree of protection associated with the added value in the production activity of the relevant commodity. The EPC values in Table 6 show that there are significant differences in the degree of policy transfer for crops across the three types of farms.

The overall impact of the existing policy results in a net positive incentive to produce sesame and groundnut crops (in mechanised farms) and millet, sesame and watermelon (in traditional farms). For irrigated farms, all crops represent a net disincentive (EPC < 1). There is either no intervention or the net impact of various distortions on both the input and product markets results in a neutral effect on the added value of the crops in the three farms.

The other PAM indicators (DRC and PPC) for the crops in each farm are reported in Table 7 and their rankings in each farm are reported in Table 8.

There is a positive correlation between protection and the lack of comparative advantage for watermelon in traditional farms. The DRC values for cotton and vegetables (in irrigated farms), sorghum (in irrigated and mechanised farm), groundnut (in all farms) and sesame (in mechanised and traditional farms) are greater than 1 and clearly smaller than those for sorghum in traditional farms.

The DRC and PPC values for millet are much larger than the respective competing crops in mechanised and traditional farms, which suggest that those farms have a comparative advantage in producing other crops rather than millet.

Most sorghum and sesame crops are produced inefficiently in Sudan, with their DRC and PPC value greater than 1. The results show government policies on sorghum and sesame crops self-sufficiency lead to significant allocative inefficiency and that there are significant differences in DRC values between the sorghum and millet crops.

Generally, the coefficient for commodities that are not in the optimal solution is greater than 1, indicating that the cost of resources (land labour and capital), when valued at their private or social shadow prices, exceed the added value when measured at its opportunity cost.

Table 7 Indicators for Sudanese agricultural farming systems' comparative advantage (2005–2006)

		Farm		
Crop	*Indicator*	*Mechanised*	*Irrigated*	*Traditional*
Cotton	DRC		1.25	
	PPC		0.69	
Sorghum	DRC	1.00	1.00	4.63
	PPC	0.05	0.19	4.02
Groundnut	DRC	1.49	1.26	1.09
	PPC	2.11	1.093	0.97
Sesame	DRC	1.03		1.98
	PPC	1.32		1.74
Millet	DRC	3.20		10.06
	PPC	3.90		8.79
Vegetables	DRC		1.32	
	PPC		0.63	
Watermelon	DRC			0.51
	PPC			0.45

Source: Calculated from authors' model, 2005–2006

Table 8 Comparative advantage ranking by crop

Farm	*Crop*	*DRC*	*PPC*
Mechanised	Sorghum	1	1
	Groundnut	3	3
	Sesame	2	2
	Millet	4	4
Irrigated	Cotton	2	3
	Sorghum	1	1
	Groundnut	3	4
	Vegetables	4	2
Traditional	Sorghum	4	4
	Groundnut	2	2
	Sesame	3	3
	Millet	5	5
	Watermelon	1	1

Source: Calculated from authors' model, 2005–2006

5 Policy implications

The results of this study have important policy implications for future priorities in poverty reduction, currently handled by the federal ministry of economic and finance.

- rural education should be afforded the highest priority, *i.e.*, the government should shift its attention to rural education
- there is an urgent need to reduce the incidence of diseases and mortality by establishing and/or increasing the supply of health services centres in rural areas
- drinking water sources should be safe with adequate sanitation
- comply with competitive prices by reducing the input costs and increasing the yield per unit area of rural poor
- self-sufficiency could be achieved with smaller losses via the reduction of input market distortions.

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Notes

1 Equation (1) is referred to as the Foster-Greer-Thorbecke (FGT) equation. It defines a family of measures of absolute poverty in any welfare dimension, which vary according to the choice of poverty line and the choice of parameter α.

2 For more information of the linkages between agricultural growth and rural and urban poverty, see Johnson and Mellor (1961) and Timmer (1995).